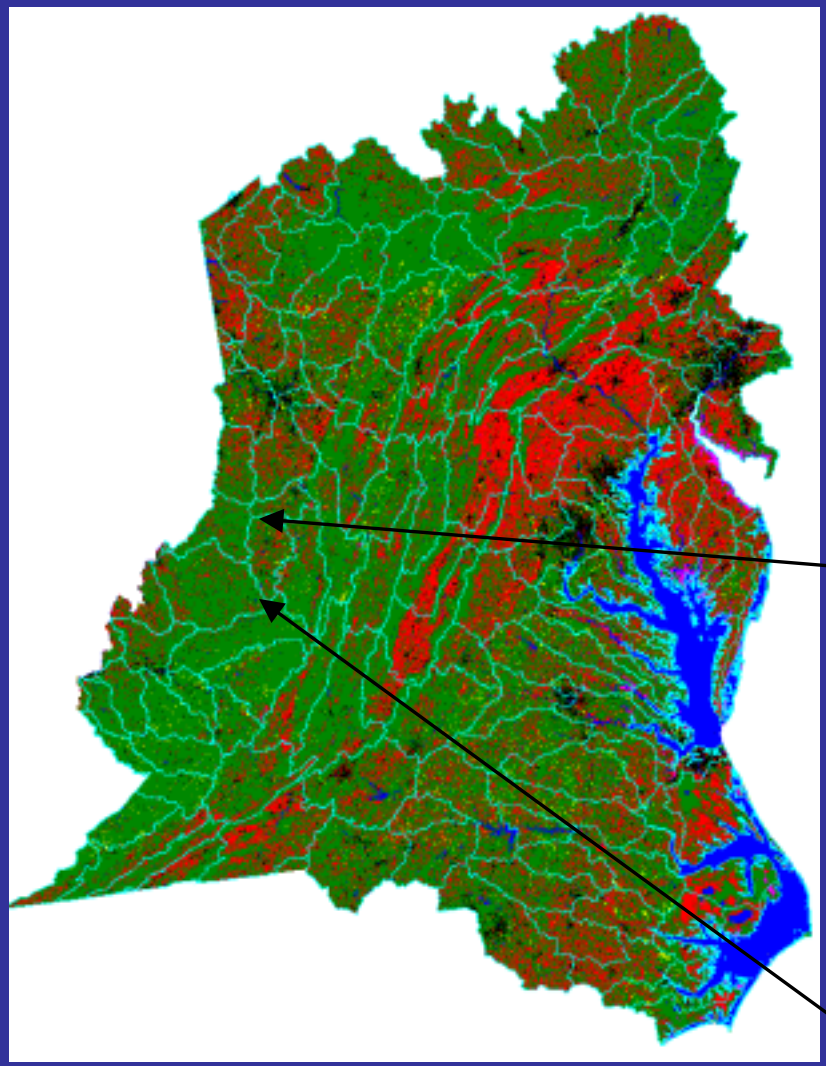
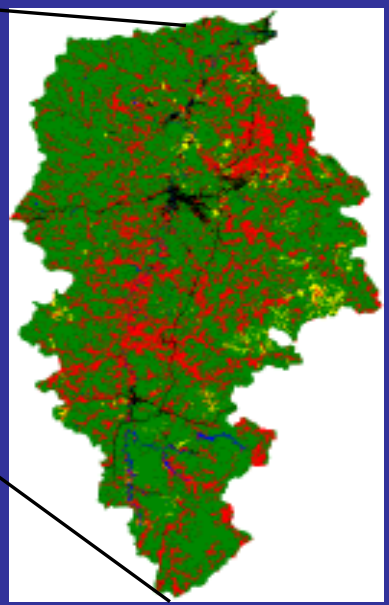
Indicators and Questions for Vulnerability Assessments at Regional to Local Scales

Betsy Smith, ORD, NERL

smith.betsy@epa.gov

ReVA is Multi-Scaled





- *Coarse filter to identify problems*
- *Approach and methods transferable to other scales*
- *Demonstrating applications at finer scales through client partnerships*

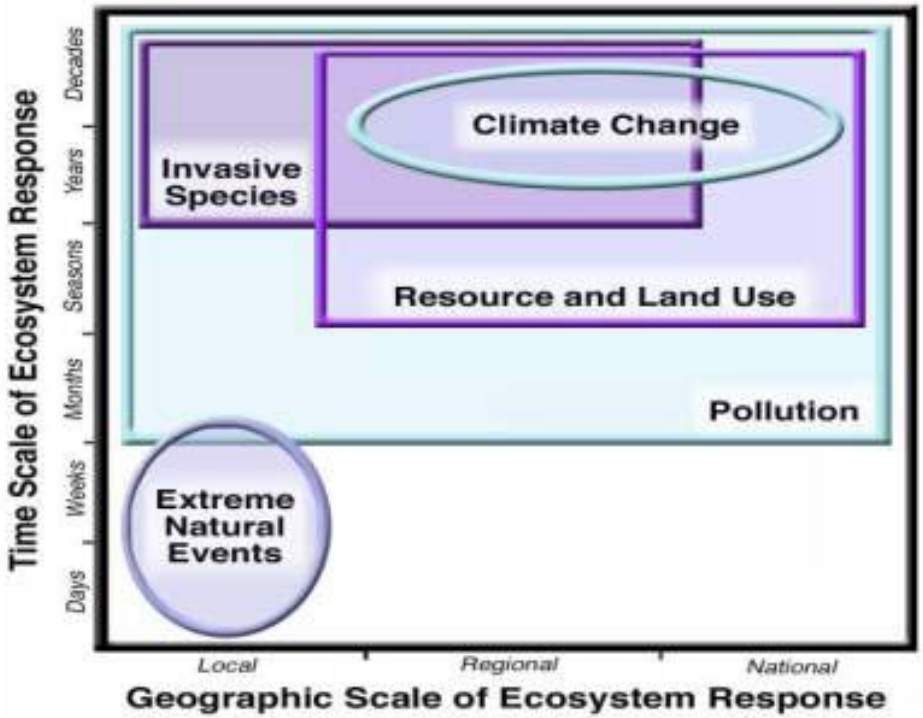
Scale and Ecological Forecasting: why the broad scale is important to decision-making at the finer scale

Forecasts of broad-based, long-term effects are particularly important because *some of the most severe and long-lasting effects on ecosystems may result from chronic influences that are subtle over short time frames.*

Landscape pattern and *contagion* affect the probability and extent of disturbance effects.

Broad-scale processes can constrain or exacerbate finer-scale processes.

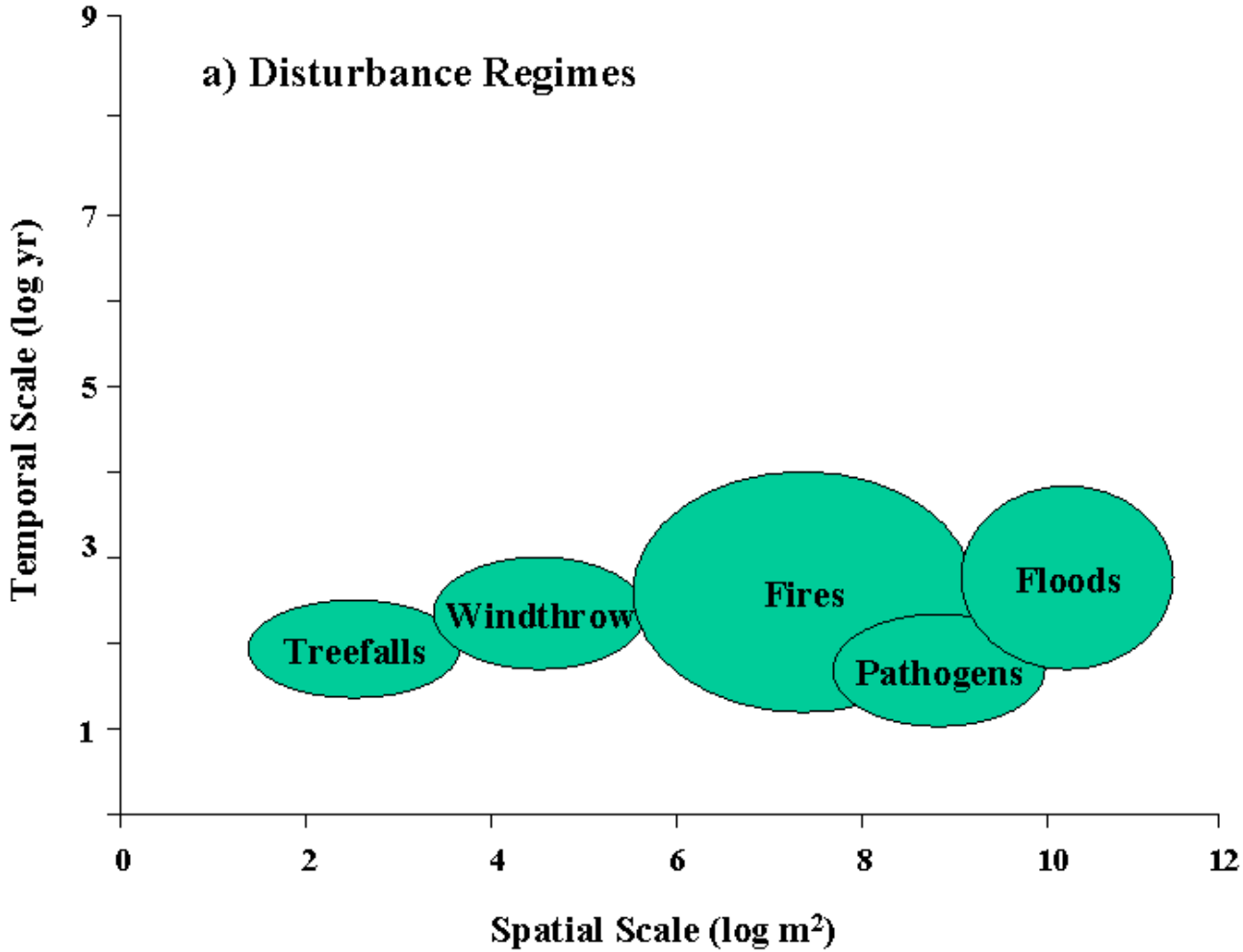
Time and space scales are linked – the assessment of ecological conditions



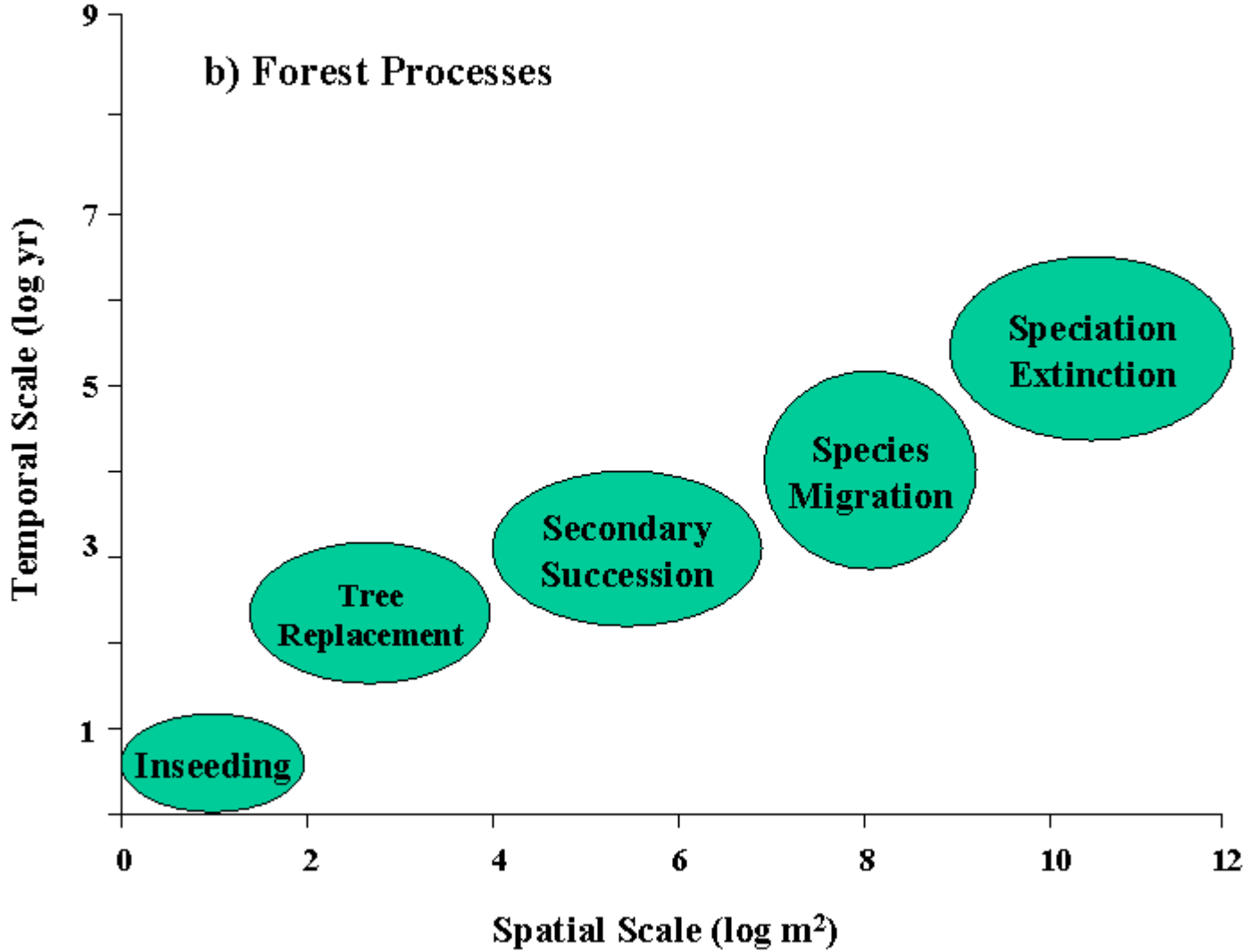
This is an important preview of why landscape ecology has emerged as an important basis for ecological assessments.

Many of the phenomena that are of greatest concern today – climate change, pollution, biodiversity, and others – are long-term and large-scale phenomena. It is not very helpful to investigate such things in local, short-term ways because knowledge of finer-scale variability often contributes little to the understanding of large systems.

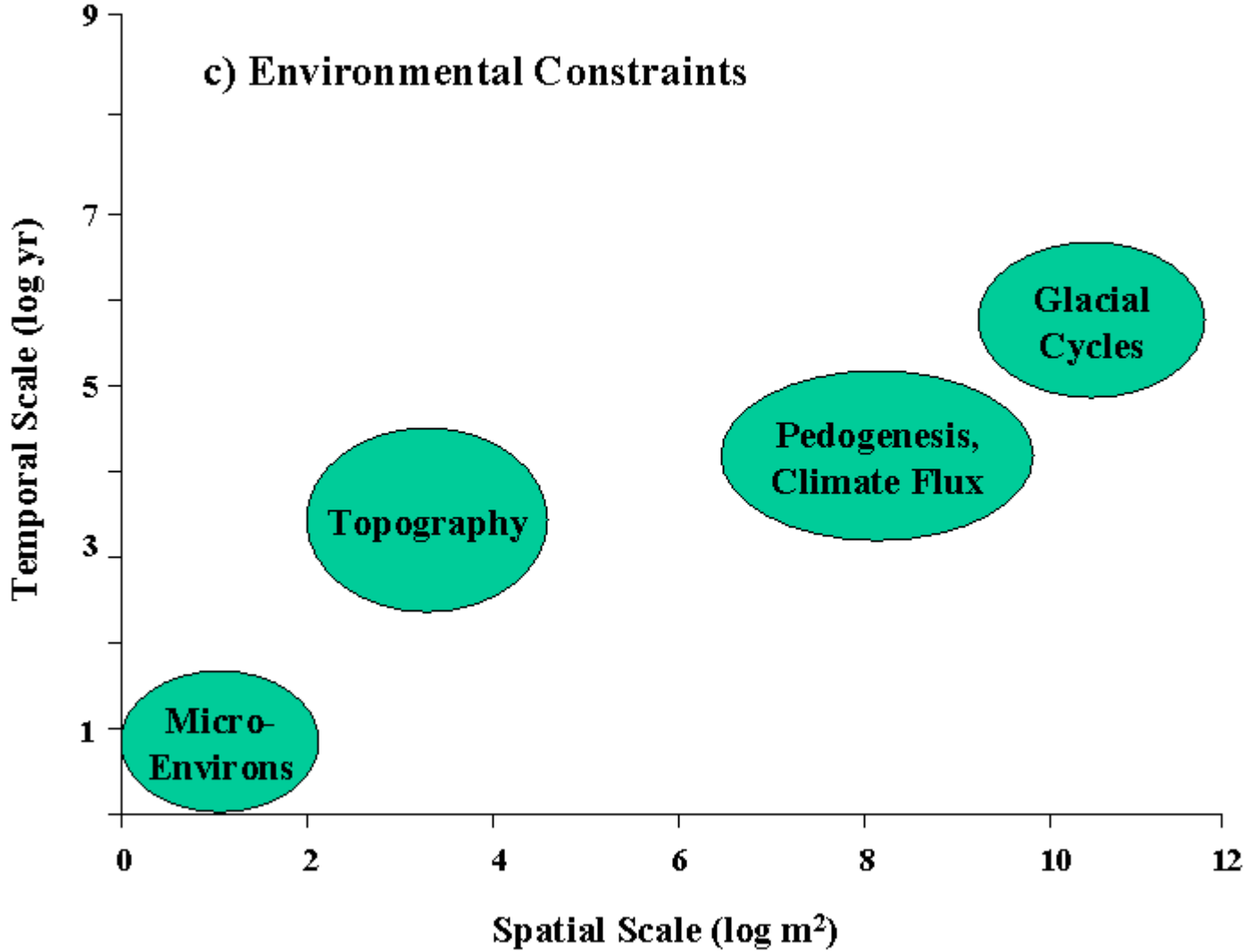
Time and space scales are linked – landscape disturbances



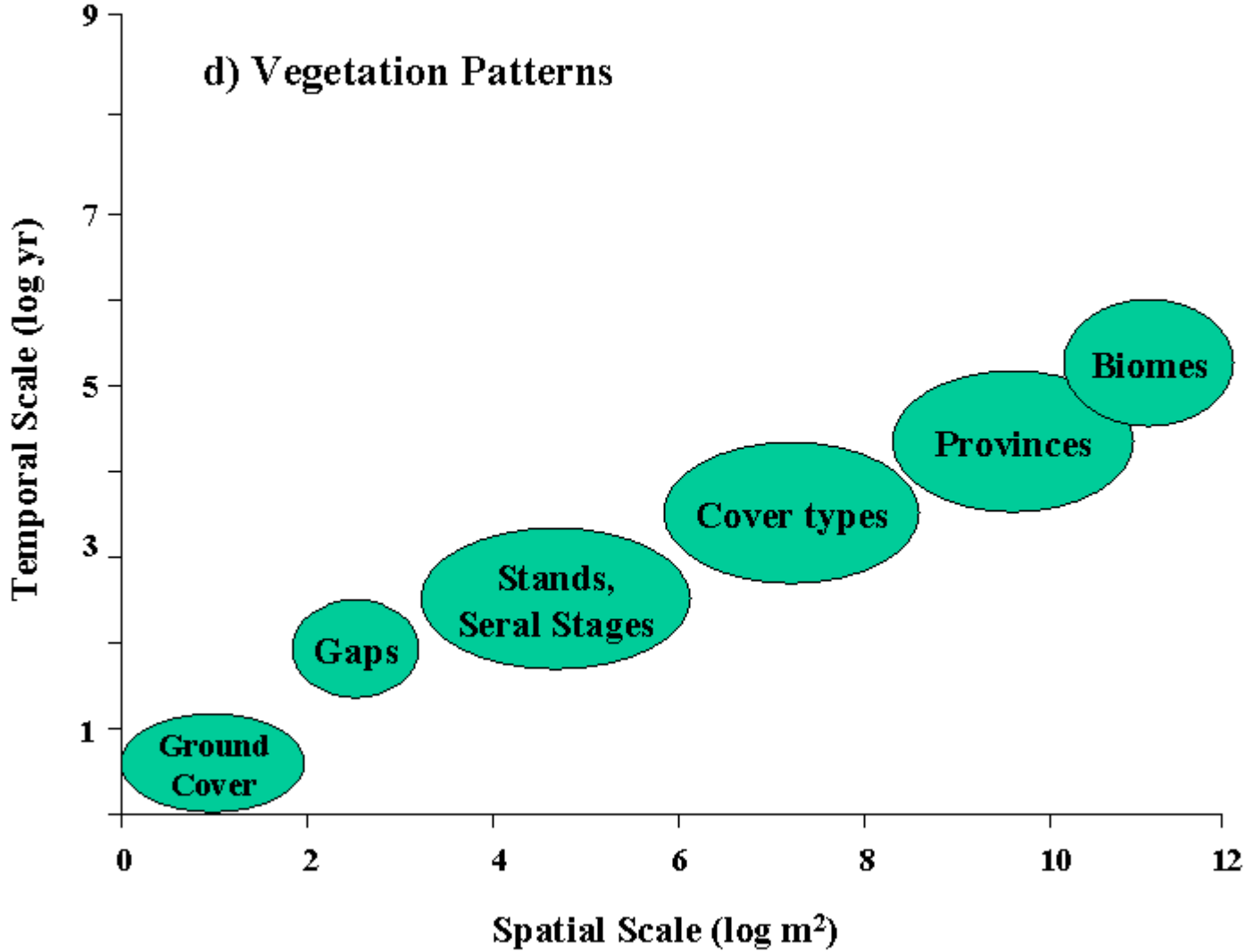
Time and space scales are linked - ecological processes



Time and space scales are linked – environmental constraints



Time and space scales are linked – creation of vegetation patterns



Contagion – effect on processes

Examples:

- Spread of gypsy moth facilitated by road networks
- Urban sprawl progresses based on neighboring land use (e.g. ag to urban is easier than forest to urban)
- Spread of forest fire influenced by stand structure

Broad-scale process effects on finer-scale

Examples:

- Climate change effect on spread of sudden oak death pathogen
- TMDL effectiveness negated without consideration of future land use change or invasive species

Effective assessment of vulnerabilities considers multiple scales

However, there are issues:

- Assessment questions are different at different scales
- Analysis scale depends on the assessment question
- Applicability of the results depends on the domain of scale

Scale of Assessment Questions

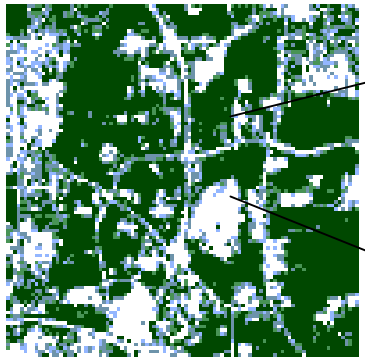
Analysis scale should be appropriate for scale of question

Example of landscape indicators and sliding window

Results in new map relevant to question

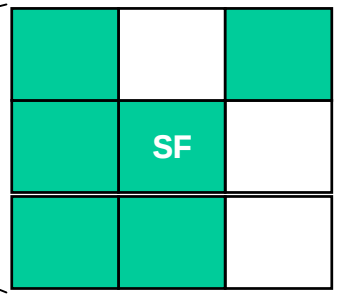
Moving window approach

A square window, representing a landscape, is moved across the map.

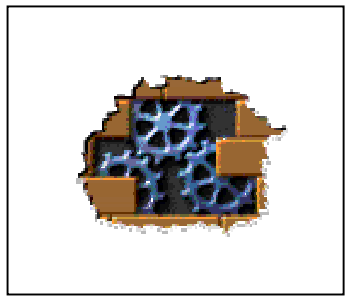


The window stops at each forest pixel (SF)

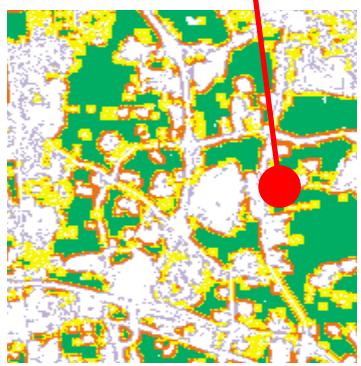
(approx 2.8 billion places)



A fragmentation index is calculated within the window

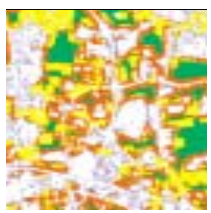


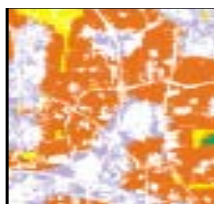
The result is mapped at the original location, making a new map



The new map shows the fragmentation context for each forest pixel

A variety of maps can be made by changing the window size and/or the fragmentation index:



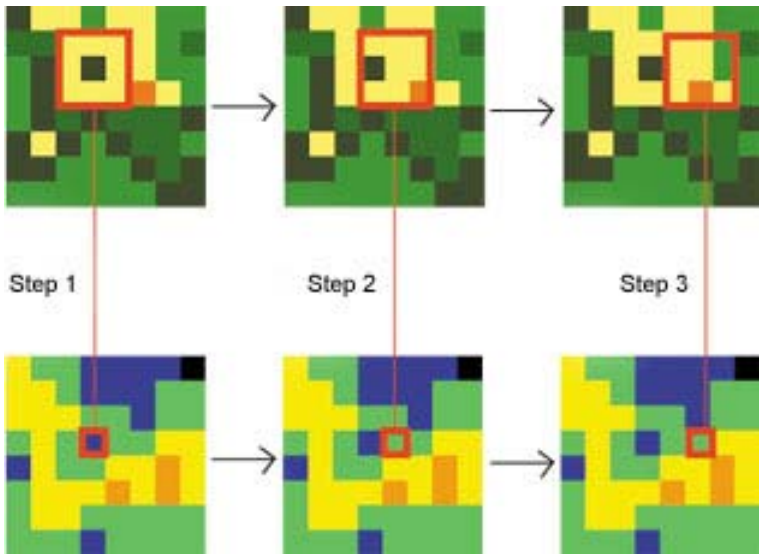


We should not expect that other organisms perceive the world in human terms.

The “game” is to specify a filter function that has ecological meaning.

A simple example:

Input = Land-Cover Map



Output = “Diversity” Map

How is the new map interpreted?

Before, landscapes were characterized by the places that they contained.

With moving windows, places are characterized by the landscapes that contain them.

The moving window approach is a more natural way to achieve "landscape characterization". Attention is focused on the context of individual places, not on the contribution that each place makes to an overall context.

A word example:

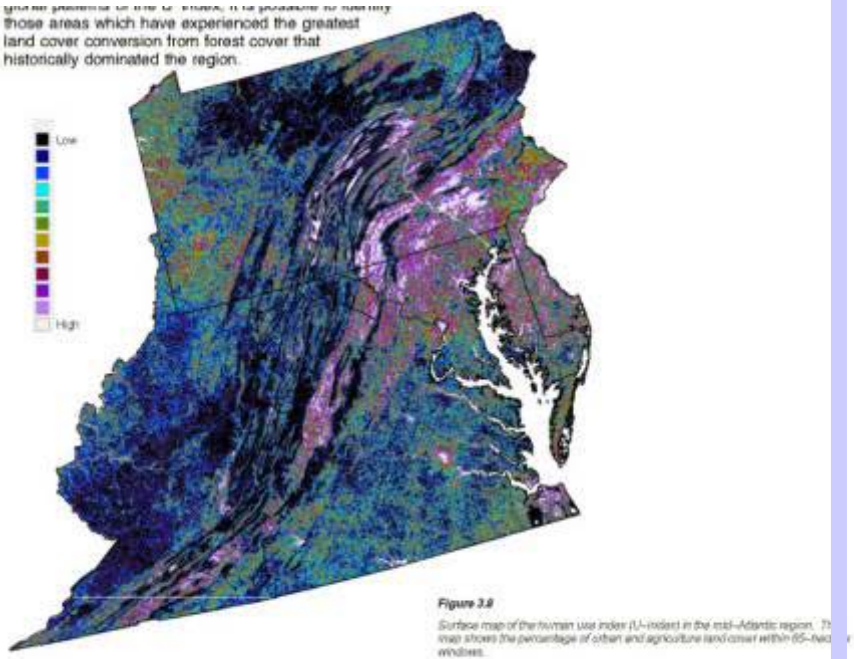
In the classical approach (non-overlapping support regions), "imagine you are standing in a watershed, and now measure all the pattern elements in the watershed, and repeat that for all watersheds"

Is contrasted with:

The moving window (overlapping support regions) "imagine you are standing on a place, and examine the pattern elements around you, and repeat that for all places"

A database of landscape *pattern* metrics from moving windows -- examples

Original land cover map (left), and a 'human use index' (right)



A database of landscape *pattern* metrics from moving windows -- examples

Original land cover map (left), and a 'landscape pattern type index' (right)

Figure 3.a.

Landcover in the mid-Atlantic region, pa. 1990. Source: Multi-Resolution Land Characteristics (MRLC) Consortium; derived from Landsat Thematic Mapper (TM) data. 30 meter resolution (closer hereafter meter resolution).

Landscape Units

Landscape analysis methods provide the opportunity to look at regional patterns of land use at a range of scales. Maps of land cover are created one pixel at a time, which ignores some of the information about local–scale patterns of land cover. By recognizing these local patterns, new landscape map themes can be created which suggest the types and intensities of human activities that are occurring in a given place. For example, if you are standing in a spot that is forested, and if most of the spots around you are also forested, then it is likely that you are in a part of the landscape that has a general land use or activity theme of "forest." If, however, your forested spot is embedded in a pattern of forest and agriculture, then it is more likely that your part of the landscape has the land use theme of "rural agriculture" instead of "forest." But land cover alone is not always an accurate guide to actual land use. For example, if the pattern surrounding your forested spot is mainly urban, then you might be standing in an area with a "city park" theme, but (without more information) it could just as easily be an area that is planned for "future development."

A landscape may be described by the relative proportions of forest, agriculture, and developed (urban) land cover it contains. The map of landscape units for the mid–Atlantic region (Figure 3.16) has 19 classes, labeled with combinations of the letters F, A, and D, referring to forest, agriculture, and developed land cover. The labels are interpreted as follows. An upper–case letter indicates an area with more than 60% of that land cover, and a lower–case letter indicates an area with less than 40% of that land cover. The ordering of letters corresponds to the relative amounts of land cover in an area. If a land cover is less than 10% of an area, the corresponding letter is left out.

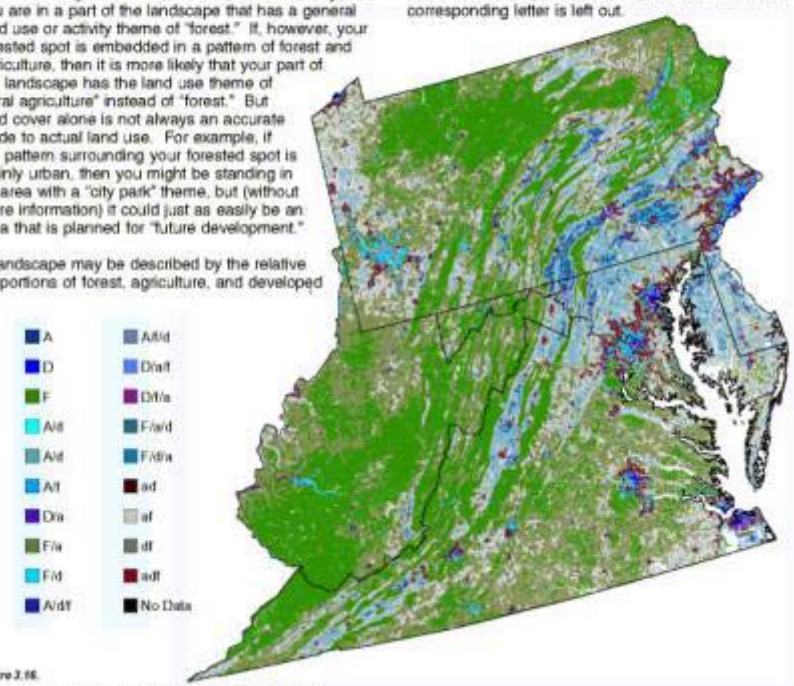
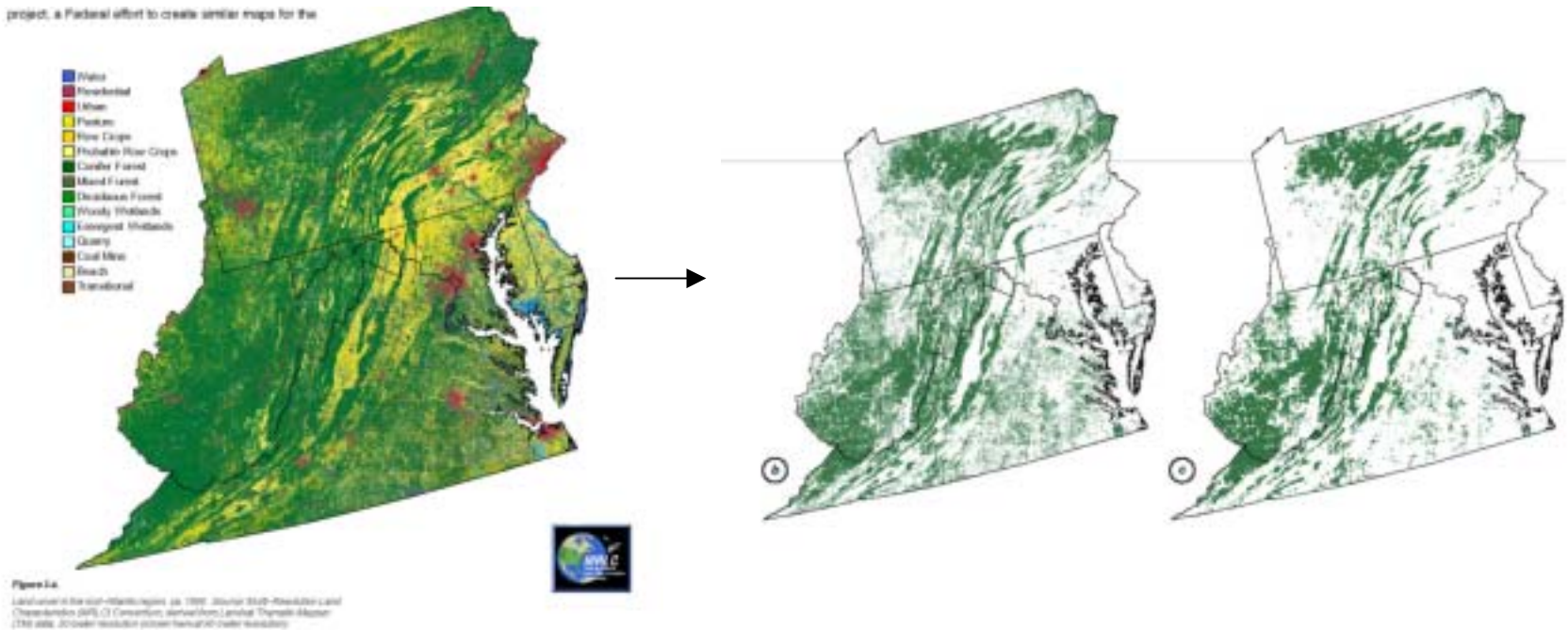


Figure 3.16.

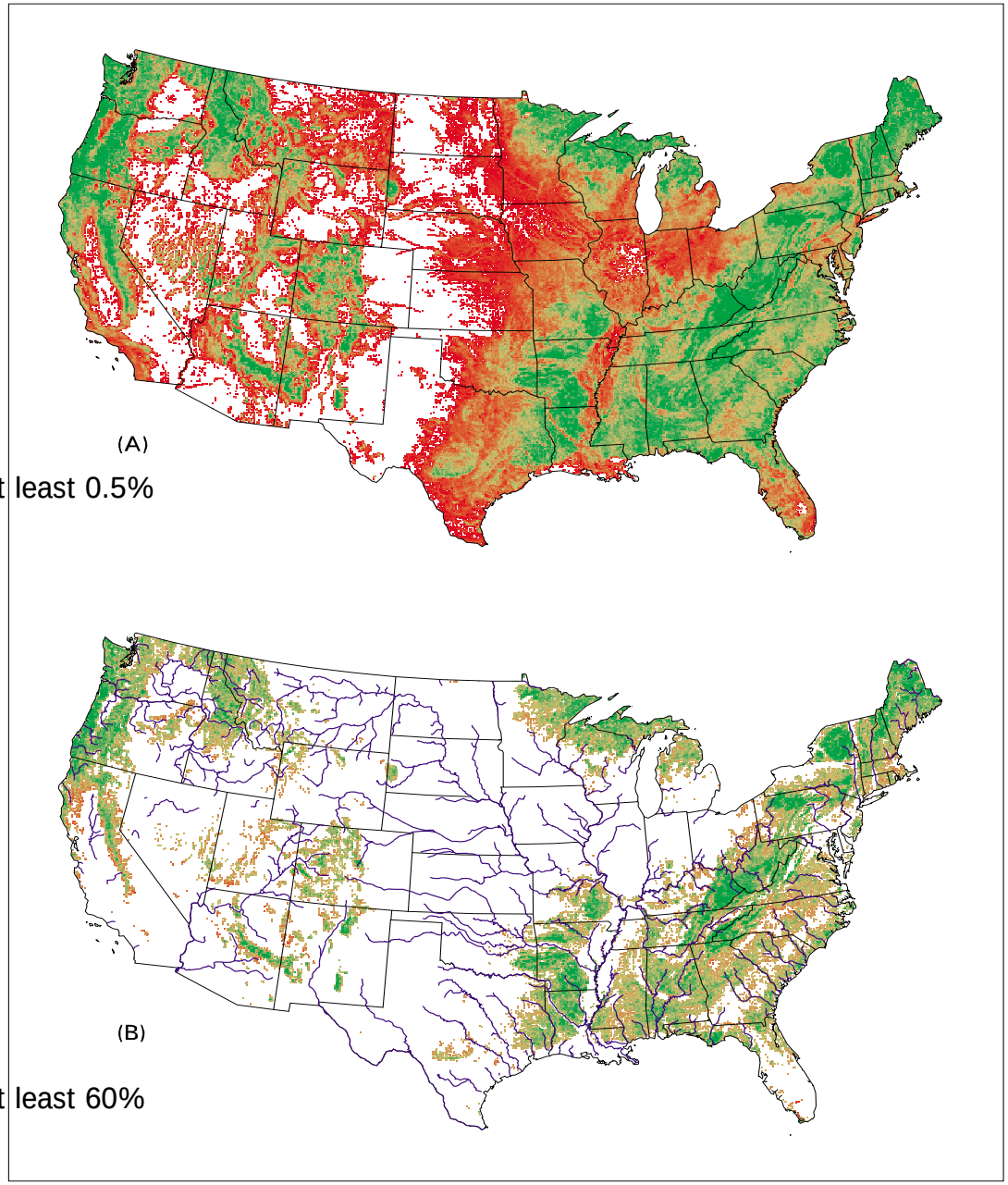
Landscape units in the mid–Atlantic region (see text for explanation).

A database of landscape *pattern* metrics from moving windows -- examples

Original land cover map (left), and a 'interior forest habitat index' at 2 scales (right)



Relative amounts of (A) forest, and (B) ‘interior’ forest in 56.25 km^2 tiles.

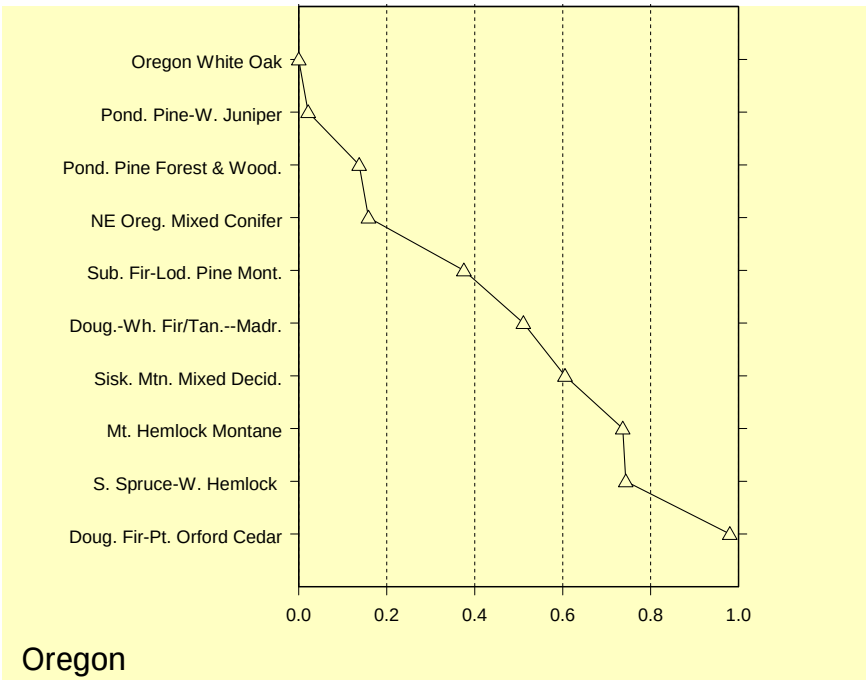


Note: tiles with at least 0.5% forest are shown.

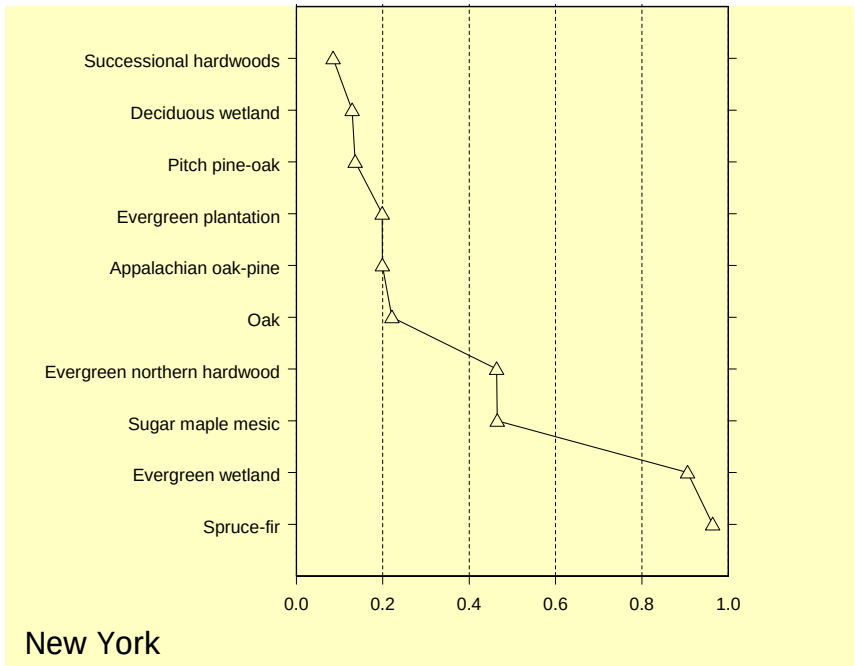
Note: tiles with at least 60% forest are shown.

Scaling Up … or Scaling Down?

National results can be “scaled down” (localized). For example, forest type maps (local) and forest fragmentation maps (national) can be combined to yield “forestland fragmentation in the vicinity of each forest type.”



Oregon

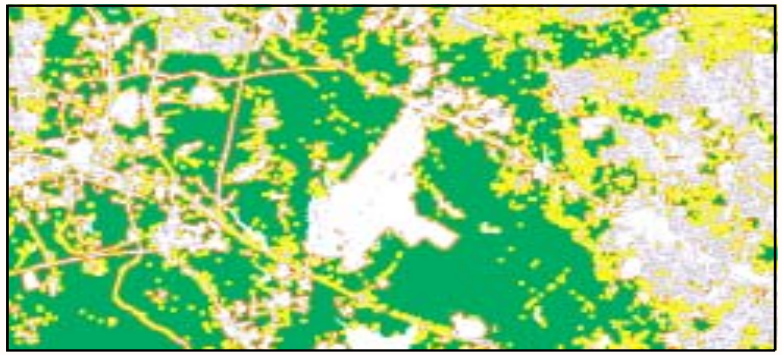


New York

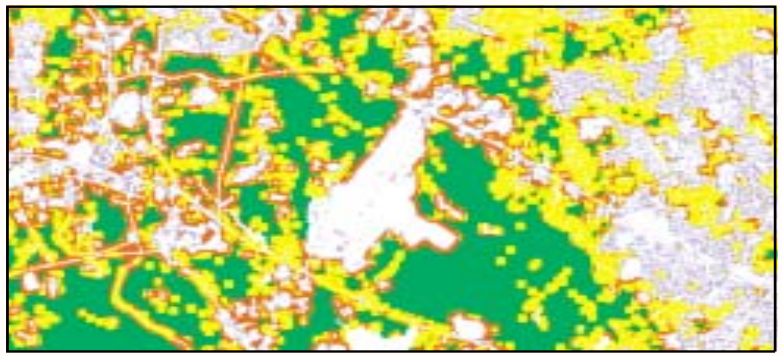
Proportion of total forest type area that is “interior” at 600-ha scale
(“Interior” is forest surrounded by 600-ha window with > 90% forest)

In contrast, local analyses of the Oregon and New York maps cannot be combined to scale up, because the underlying land-cover maps are not comparable.

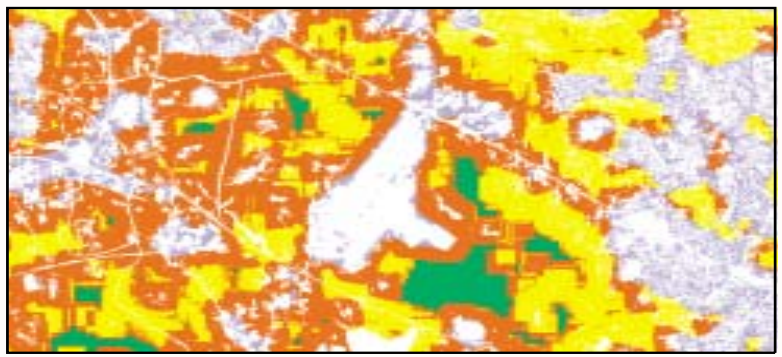
Example, continued, for 3 window sizes



2 hectare scale



7 hectare scale



66 hectare scale

- Edge
- Perforated
- Core
- Patch

Modeling Issue

Are regional-scale models applicable to finer scales?

Sometimes….

Research question: is there a metric that can be used to help determine applicability?

Regional- and Watershed-Scale Models of Ground-Water Vulnerability Based on Land Use and Other Geographic Factors

A Multi-Scale Analysis

Earl A. Greene, USGS, Baltimore, MD
Andrew E. LaMotte, USGS, Baltimore, MD

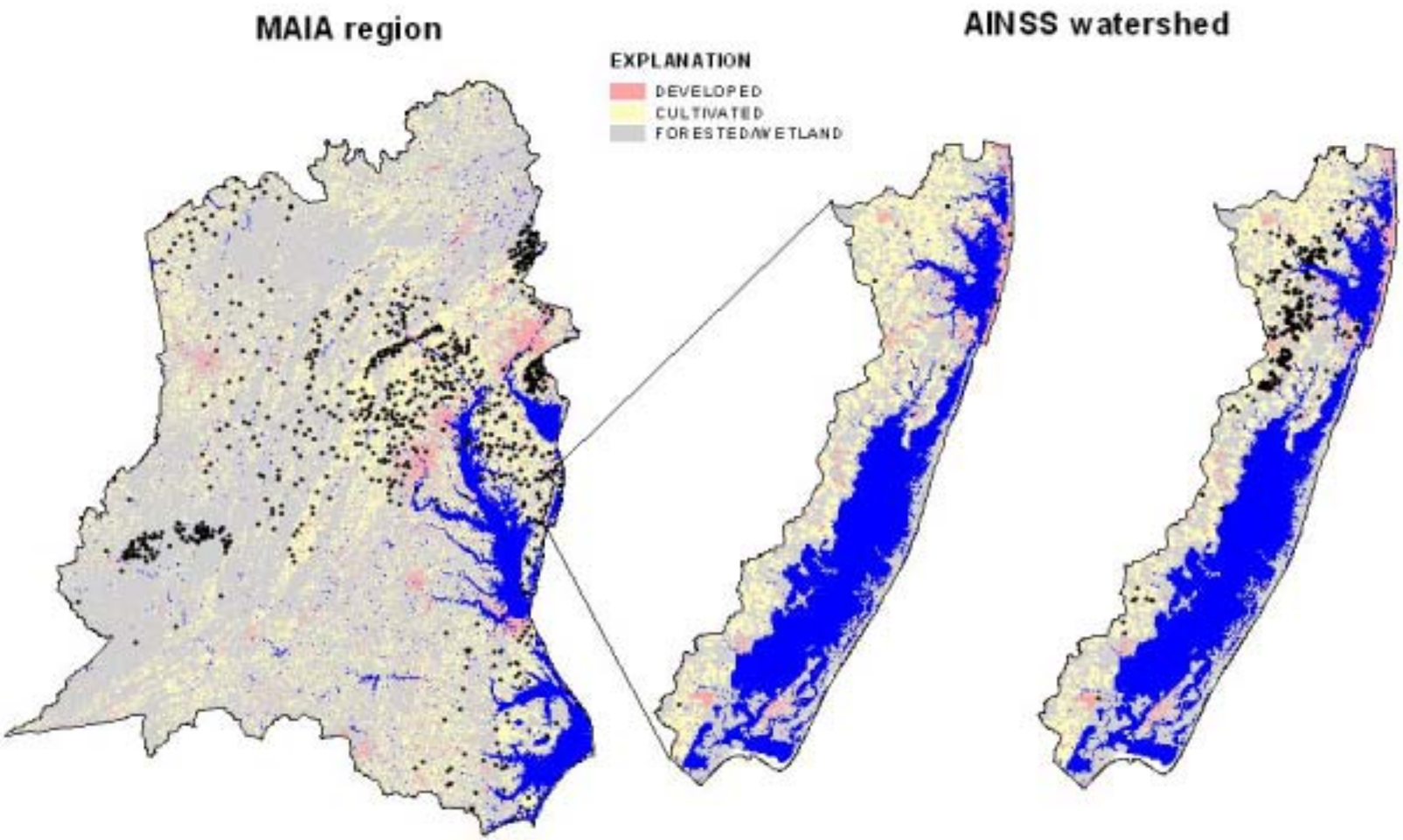
USGS
science for a changing world

ReVA
Regional Vulnerability Assessment

Regional vs. Watershed

- **Nitrates are used as a Surrogate for Ground-Water Vulnerability**
- **Data Available at Two Spatial Scales**
- **Source Data was not Subsets or Nested**
- **Both Models Address Continuous and Discrete Variables Confidence**
- **Variables with the Least Uncertainty were Extrapolated to the Other Scales**

GENERALIZED LAND USE AND LAND COVER



MAIA region showing NAWQA QW sites with the AINSS watershed enlarged for comparison

AINSS watershed showing State and County QW sites

Summary Statistics of the Nitrate Data

Region

- 926 Samples
- Mean =3.7 mg/L
- Std Dev = 5.0 mg/L
- Minimum = 0.01 mg/L
- Maximum = 29.0 mg/L

Watershed

- 534 Samples
- Mean =1.4 mg/L
- Std Dev = 1.8 mg/L
- Minimum = 0.1 mg/L
- Maximum = 19.7 mg/L

Significant Explanatory Variables

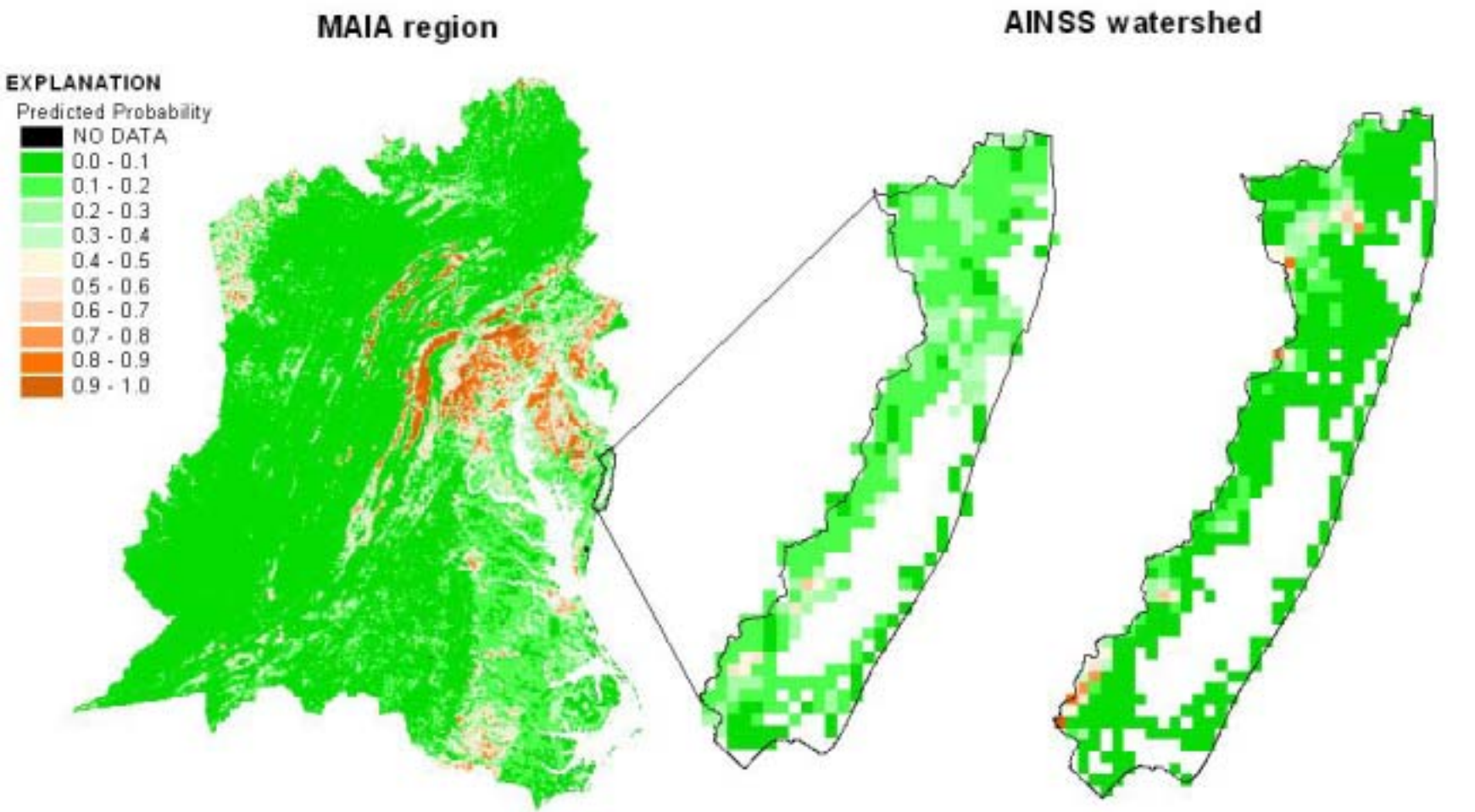
Region

- Land Use/Cover
- Geology Type
- Fertilizer – Inorganic and Manure
- Soils: Hydrologic group
- Percent Organic Matter
- Percent Silt and Clay
- Population Density

Watershed

- Land Use/Cover
- Geology Type
- Fertilizer – Inorganic and Manure
- Soils Hydrologic group
- Percent Organic Matter
- Percent Silt and Clay
- Population Density

PREDICTED PROBABILITY OF EXCEEDING 3 MG/L OF NITRATE



Predicted probability for the MAIA region with the AINSS watershed enlarged for comparison

Predicted probability for the AINSS watershed

Conclusions

- Multi-scale is most effective
  - Time and space are linked
  - Contagion
  - Broad-scale processes affect finer-scale processes
- Analysis of landscape pattern can be adapted to scale-specific questions
- Regional scale models applied to finer-scale with caution